INCREASED STIFFNESS OF VEHICLE STRUCTURE IN ACCIDENT

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part application of co-pending international application number PCT/DE 96/02120 (WO 97/18984, European Patent Doc. EP 0869878 B1, Canadian Patent Doc. CA 2,220,872) filed Nov. 7, 1996.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates generally to vehicle doors and, more particularly, to interengaging assemblies which structurally integrate all vehicle doors, when closed, with the vehicle roof, both side rails (sill portions) arranged along the vehicle floor, all pillars (post sections or pillar portions) and the flanges of door apertures of a vehicle body thereby distributing energy to all those vehicular members, lowering stress thereof, preventing passenger ejection and enhancing survival chance in the event of any collision (front, side and/or rear collision) or rollover.

2. Discussion of the Prior Art:

In order to formulate in single terminology a generalized definition for the proper term is presented:

Definition:	Proper Term:
"vehicle door (**8, 8B, 8T, 8h, 8x**)"	tailgate- (**8T**), sliding side-, cargo-, liftgate door, trunk cover (**8x**), hood (**8h**) or vehicle door (**8, 8B**)
"juxtaposed doors"	doors of a vehicle side are in juxtaposition
"girder"	panel, shell, beam etc. according to FEM and Technical Mechanics
"window-guide channels"	window-pane tracks **6, 6B, 6.1, 6.2, 6.1B, 6.2B, 6.1a, 6.2a, 6.1aB, 6.2aB** to house und guide window panes (glasses)
"door cavity"	space between the outer and inner panel of the door
"door detachment"	vehicle door becomes detached from the vehicle body
"engaging members of interengaging assembly	engaging members of an interengaging assembly such as key & receptacle, hook & recess, hole & key or hook & rod
"engaging hole"	aperture, slot, oblong hole
"real-world accident"	front-, side-, rear collision and/or rollover
"vehicular couple"	two mating vehicular members, such as vehicle door & vehicle roof, vehicle door & side rail, vehicle door & flange (transition region) of vehicle body, vehicle door & pillar/s, vehicle door & vehicle door in engagement in real-world accidents

It is known in the prior art to provide interengaging assemblies to engage and/or clamp the vehicle door with the mating vehicular members, when the vehicle door is in closed position, in order to distribute energy to the vehicular members and lower stress thereof as well as accelerations thereto passengers or dummies are exposed at low crash speed either in mid-front collisions or in side collisions of type „U2", one of four types shown in **Fig.** 13, or in crash tests. However, all these conventional configurations has not taken into account the following problem cases associated with failure of interengaging assemblies resulting in overstress of vehicular members, severe/fatal injuries linked to intrusion of vehicle side, door detachment and/or passenger ejection in real-world accidents (front-, side-, rear collisions or rollover-accidents).

- **A** Load cases **I to V** according to Technical Mechanics/FEM in real-world front, side and rear collisions;
- **B** Wrong assumption of the prior art for the purpose of idealizing a general side energy „S" or „S_1" to a single energy „S_x" or „S_{x1}";
- **C** Analogy between the state of non-contact and disengagement;
- **D** Constant, small contour-clearance and assembly tolerance zones;
- **E** Large clearances of mating engaging members of interengaging assemblies;
- **E1** The first inventions of interengaging assemblies, huge production costs and fatal injury in a real-world collision due to large clearances;
- **E2** Large deformation of vehicle structure or door **8. 8B** in a real-world collision;
- **E3** Large deformation of side rail **18** in a real-world collision;
- **E4** Large deformation of upper member **8.17** of door frame and vehicle roof **17** in a real-world collision;
- **E5** Intrusion of vehicle roof **17** in vehicle body **20** in a real-world rollover-accident; and
- **E6** Clamping assemblies or adjustable interengaging assemblies to resolve problem case **E**.

Problem case **A**: In order to idealize an impact force „$2F_1$", shown in **Fig.** 10A, imposed on a vehicle structure the following assumptions must be specified:

– let the vehicle structure be idealized by two symmetric vehicle halves subjected to an front impact force „2F" along the centre line.

Load case **I** in z-y plane, shown in **Fig.** 5: The moment „$M_x = H*h$" about the x-axis is replaced by a pair of forces „$H_A = (H*h)/l$" with the lever arm of „l". Employing the equilibrium condition for moments two forces of reaction are obtained: „$V_A = (V*l_C)/l$" and „$V_B = -V_A + V$". Acting in z-direction with respect to the sign are three shear forces: „-V", „$(H_A + V_A)$ " and „$-(H_A + V_B)$". Under load of these forces the vehicle side, comprising all pillars, juxtaposed doors **8, 8B** reinforced by impact elements and interengaging assemblies of those doors and pillars, is subjected to the bending moment along the y-axis.

Load case **II** in z-x plane, shown in **Fig.** 6: The force „V exerts bending moment „M_{zx}" along the x-axis and rotating moment „$M_y = V*b$" about the y-axis acts as torsional moment along the vehicle side.

Load case **III** in x-y plane, shown in **Fig.** 7: The A-pillar is under load of rotating moment „$M_{xy} = -H*b$". The vehicle side is subjected to bending moment „M_{xy}" along the y-axis and buckling force „H".

Subjected to the total stress of bending moments „M_{zx}", „M_{xy}", „M_{zy}", buckling force „H" and torsional moments „M_z", „M_y" in the load cases **I to III**, the vehicle side, shown in **Fig.** 8, is deformed in a real-world front collision.

By reversibly arranging the juxtaposed doors **8, 8B** the same load cases are obtained for real-world rear collisions.

Load case **IV** in x-y plane, shown in **Fig.** 9: Under load of side impact energy „S" at impact angle „$\alpha = 27°$" according to FMVSS 214 or in the event of real-world side collision the vehicle side is subjected to bending moment „M_{xyS}" along the y-axis and lateral force „S_y". Load case **V** in z-x plane, shown in **Fig.** 10: Under load of side impact energy „S" at impact angle „γ" or in the real-world side collision against a tree or highway column **22**, shown in **Fig.** 10A, 13, the vehicle side is subjected to bending moment „M_{zxS}" along the z-axis and lateral force „S_z".
The total stress is defined by the stresses in load cases **IV** and **V**.

Problem case **B**: The majority of the prior art is governed by the following assumptions:
- let clearances between mating members of an interengaging assembly be neglected and
- let the load cases **IV** and **V** be idealized to a lateral energy „S_x", shown in **Fig.** 9, or „S_{x1}", shown in **Fig.** 10A, imposing on the *centre* of vehicle door, illustrated as collision type „U1", shown in **Fig.** 13, despite four collision types „U1 to U4" and the collision type „U2" having the highest percentage of severe and fatal injuries. Nevertheless, car manufacturers and suppliers world-wide have always adopted this idealized „S_x" or „S_{x1}" in inventions, for example, U.S. Pat. No. 4,307,911, U.S. Pat. No. 5,806,917, U.S. Pat. No. 5,518,290, whose shortcomings are mentioned in the following problem case **E2**.

Problem case **C**: Ref. to **Figs.** 11, 12 both end coils of compression-coil spring **19** are guided by two spring seats **19.1**. Their utmost outer nodes „KN_i" and „KN_{End}" (not drawn) rest against both stops **19.3**, where „i" represents the number of coils. To survey the behaviour of end coil **19** rolling on the lower spring seat **19.1** the end coil is idealized in elements where two nodes of each element are supported by springs having a threshold governed by a distance „s". The element is in the state of rolling when „$s < 0.1$" mm. **Fig.** 12 illustrates the rolling behaviour in regard to the FEM data and test results marked with „M" in dependence on „F_z" = -790, -1000 and -3000 N:
- According to test results „KN_2" to „KN_5", rolling on the spring seat at „F_z = -790 N", are in the state of rolling but in the state of non-contact at „F_z = -1000 and -3000 N".
- According to FEM data the nodes in the following states are in dependence on „F_z":

F_z	State of contact	State of rolling
-100	KN_1, KN_{15}, KN_{17}	KN_1 to KN_3, KN_{10} to KN_{18}
-250	KN_1, KN_{19}, KN_{20}	KN_1, KN_{15} to KN_{23}
-1415	KN_1, KN_{17}, KN_{19}, KN_{20}, KN_{30}, KN_{31}, KN_{33}, KN_{34}	KN_1, KN_{15} to KN_{35}

The state of contact (engagement) of mating members of interengaging assemblies, idealized by elements of the spring rolling on the spring seat, can be transformed into a state of rolling (detachment), when the force increases.

Problem case **D**: Recently in automotive industry, great efforts have been made to achieve (finish) a constant (uniform), small contour clearance between the outer door-contour "abcde" of vehicle door **8, 8B** and the door aperture (opening) of vehicle body **20**, shown in **Fig.** 5, when the door is closed, in order to minimize flow noise and, particularly, to achieve sales success resulting from an overall impression of attractive design. In the state of assembly the contour clearance, for example, of AUDI ® vehicles is only 2.5 mm and of VW Passat ® 3.5 mm.
In order to meet the above-mentioned goal and to avoid rework or high reject rate large assembly tolerances between the outer door-contour and the door aperture must be designed.

Problem case **E**: The catch plate of door lock **248**, rigidly attached to vehicle door **8**, and the striker **298**, rigidly attached to pillar illustrated as B-pillar in **Fig.** 10A of U.S. Pat. No 4,307,911 representing the prior art, is provided with locking clearances in x-, y- and z-direction, thus ensuring the state of door locking and the normal operation of vehicle door. For the purpose of preserving the constant, small contour-clearance,

- the position „D_a" to „D_c" of each key **128a to 128c**, rigidly attached to vehicle door **8**, and the position „S_a" to „S_c" of mating receptacle **158a to 158c**, rigidly attached to lower stiff panel **156** of side rail **18**;
- the position „D_n" of key **148**, rigidly attached to vehicle door **8**, and the position „B_n" of mating receptacle **198**, rigidly attached to pillar,

must be provided with position-tolerances, **larger** than locking and assembly tolerances, in x-, y- and z-direction in order to avoid

1. interference with the locking operation of catch plate of door lock **248** to striker **298** when closing vehicle door **8**;
2. expensive reworking at the assembly line;
3. customer complaints due to disturbing noises linked to small distances of overlaying coils, representing the mating members of interengaging assemblies, denoted as „$w \leq 0.2$ mm", shown in **Fig.** 11; and
4. high reject rate due to different references of coordinate system of vehicle doors, finished by two to three suppliers and transported to an assembly line, and of a vehicle body **20**, finished at the assembly line. Huge costs are necessary to computerize design data of the vehicle doors and structure in data files, which must be evaluated by innovative programs to minimize those position-tolerances and reject rate, however, under the condition of the constant, small contour-clearance.

Problem case **E1**: According to the prior art the taper-formed key **148** and the mating receptacle **198** should be in engagement or form-locking connection to ensure energy-transmission from one pillar to the other.
Because receptacle **198** and striker **298** are formed together in one piece, an adjustment of receptacle **198** changes the position of striker **298** to the catch plate **248** as well as the clearance therebetween, which becomes too large or small. In order to properly latch and lock the vehicle door to vehicle structure the "interengaging" assembly is provided with large tolerance zones, thus violating the condition of the aforementioned feature.
When a vehicle is laterally crashed by a truck, the key **148** can disengage from mating receptacle **198** due to large clearance so the remaining energy totally deforms the vehicle door, whose intrusion can fatally injure the driver.
According to the prior art shown in **Fig.** 1A, contour tongues **16.1** should be in engagement with contour grooves **16.2** in order to integrate vehicle door **8, 8B** into side rail **18,** vehicle roof **17** and B-pillar in a side collision. Without "interengaging" assembly of the vehicle door and B-pillar, the normal operation of vehicle door would be possible if the outer door-contour "abcde" were square. Regarding the recent contour design, shown in **Figs.** 5 and 18, the line "ab" is generally curve-shaped, line "bc" of front door upwardly inclined ($\beta > 90^0$) or generally curve-shaped and line "bc" of rear door generally S-shaped, so contour grooves **16.2** would interfere with contour tongues **16.1** when closing the vehicle door.
Furthermore, to sustain large impact energy it is necessary to reinforce the wide contour groove by an element which, unfortunately, can't be attached to the narrow upper member **8.17** of door frame.
According to the U.S. Pat. No. 3,819,228 a bulky "engaging" bolt rigidly attached to a stiff inner panel of vehicle door **8** projects through a hole of a stiff element attached to side rail **18** when the door is in closed position. The problem of large tolerance zones remains unresolved. Moreover, the overall stylish impression spoilt by a bulky "engaging" bolt will,

doubtless, not be beneficial to sales. When stepping in or out of the vehicle body while cleaning or repairing, the person can injure himself when stumbling over this bulky bolt. When closing the door the danger of damage to clothing and injury to passengers, particularly when it is dark, is apparent.

Problem case **E2**: Under the load of force „F_1", shown in **Fig.** 10A, in an approx. 30^0 inclined, offset front collision against another car the vehicle structure, totally deformed, is deflected, in a great extent, in the opposite x-direction and in the y-direction thus resulting in disengagement of the catching hook **148**, rigidly attached to the impact beam **1, 1B** of driver-door, and the catch plate **248** from the mating recess **198** and striker **298**, all of which are rigidly attached to the B-pillar, in association with the reduction of the distance between the A- and B- pillar from 860 mm to 490 mm in the y-direction and the collapse of passenger protection. Later on, the remaining energy totally deforms the driver-door too. If the car rolls over, the driver will be ejected therefrom.
In a real-world side collision of another car. equipped with a catching hook **148** ref. to U.S. Pat. No. 5,518,290, into a tree, great energy totally deformed the vehicle side whose intrusion fatally injured both front-seated passengers because the catching hook **148** could not penetrate into recess **198**.
Mating members of interengaging assemblies fail to engage because the real force in both and other real-world accidents is wrongly replaced by the idealized force „S_{X1}" or „H_1", shown in **Fig.** 10A.

As exemplified by U.S. Pat. No. 5,806,917, tapered (wedge shaped) keys, located on the front, rear, upper and lower edges of the door, engage mating receptacles, located on the door jamb, the roof and side rail, when the door is closed. Four clearances, associated with four faces thereof, and a depth clearance are accounted for loose engagement of each tapered key with the mating receptacle. On the use of six interengaging assemblies the structural connection of door **8** with vehicle body **20** has 6 x 5 = 30 clearances plus three clearances between the stud **298** and catch plate **248**, shown in **Fig.** 10A, thus totalling 33 clearances, which must be designed large in order to avoid the interference of interengaging assemblies in each other. The drawback of large clearances could be avoided by injecting hardenable resin in the receptacles. Huge costs result from stopping the assembly line, meticulously measuring all 33 clearances, which must be adjusted to permissible tolerances, and repairing when the remaining resin smears the vehicle body and/or resin spills thereover. Disadvantageously, hardenable resin coatings are incapable of sustaining great forces in an accident.
When the vehicle body deflects in the opposite x-direction, the interengaging assemblies with large clearances are disengaged. In general, large clearances are responsible for the collapse of vehicle structure in real-world accidents.
As exemplified by U.S. Pat. No. 4,676,524, a pair of vertically supporting window-guide channels, rigidly mounted in both vehicle doors **8** of a convertible car is in abutting, "engaging" relationship with both termini of upper member of cowl, when both vehicle doors are in closed position, owing to a pair of "interengaging" assemblies, each of which consists of

1. a receptacle of the terminus of the upper member and a locking mating tip of key of the window-guide channel pressing therein in the first embodiment; or
2. a king-size hole of the terminus of the upper member and a mating key of the window-guide channel having a mushroom-shaped head being in free connection therewith in the second embodiment

for the purpose of enhancing survival chance in a rollover-accident.

When the convertible car rolls over,

1. great shear force fractures each locking tip of the key; or
2. great impact energy totally deforms each "interengaging" assembly resulting in failure thereof.

thereby totally deforming the cowl and pair of window-guide channels.
The stiffness of an open roof of a convertible car, merely supported by a pair of pillars in force-locking or free connection with one pair of small-size window-guide channels, is

- very low, thereby resulting in fatalities on a real-world rollover thereof;
- lower than that of a rotatable, stiff rollover bar;
- far lower than that of the closed roof **17** supported by two pairs of pillars and
- substantially far lower than that of the closed roof **17** strongly supported by three pairs of reinforced pillars.

Problem case **E3**: Due to great energy in a real-world side collision against column **22** of a central barrier, shown in **Figs.** 10A, 13, on a highway

- large deformation of side rail **18** and rear section of a vehicle, opposite to x-direction, caused the disengagement of the driver's less deformed door **8** from a vehicle structure and later on
- the two-door vehicle rolled over three times across the highway and down-hill, thus totally deforming vehicle structure, front doors **8**, tailgate-door **8T**, out of which both rear passengers were hurled, and, alternately, opening and closing both front doors **8**, out of which both front passengers were hurled out.

Grass **70** clamped between each pillar and each front door **8**, shown in **Fig.** 8, was an evidence for the alternate opening and closing of both front doors **8** during the rollovers.
In a side collision of another car into a tree great energy totally deformed vehicle door **8**, whose intrusion severely/fatally injured the front-seated passengers.
In a collision of another car into a hill great energy totally deformed the right side rail **18** thus resulting in detaching the catch plate **248** from the mating striker **298** and later on totally deforming vehicle structure when rolling over during which the driver was hurled out thereof.

Problem case **E4**: In a front collision or crash test impact energy deforms, in general, upper member/s **8.17** of door frame/s outwards and vehicle roof **17** upwards, thereby creating a gap „o", shown in **Fig.** 8, and preventing front vehicle door/s **8, 8B** and/or vehicle roof **17** from transmitting energy to vehicle body **20**.
In three crash tests, conducted by a German Vehicle Club ADAC, German vehicles of the same type are 40 % offset crashed at the same speed of 50 km/h into

- a very stiff barrier,
- a deformable barrier and
- another vehicle of the same type

As a result, three different states of deformation are obtained because the uniform load, deformable property of two masses, impact condition etc. are different. However, the gap „o" in three different sizes, shown in **Fig.** 8, verifies the above-mentioned thesis of non-transmission of energy.

In a side collision impact energy deforms, in general, upper member/s **8.17** of door frame/s inwards thereby inflicting injuries on head.

Problem case **E5**: During the rollover of a car, impact energy totally deformed vehicle roof **17** whose intrusion severely or fatally injured both front passengers, whose heads were, definitely, crushed by falsely deployed airbags, and the remaining energy totally deformed vehicle body **20** and doors **8, 8B, 8T, 8x**.

Problem case **E6**: Responsive to problem case **E**, a clamping assembly illustrated in **Fig.** 1B comprises

- a stiff hook of stiff ledge **25.2** rigidly mounted to lower door frame **8.18** and
- a thin mating panel of stiff plate **25.1,** rigidly attached along sill rail **18**, serving as a site of predetermined fracture.

In excess of predetermined value in a real-world side accident, the mating members **25.1, 25.2** of interengaging assemblies are in the state of clamping to ensure the permanent engagement of lower door frame **8.18** with sill rail **18** in order to resolve the problem of passenger ejection. Load cases **I to III, V** and problem cases **E2 to E5** remain unresolved. Furthermore, there is no space to house both mating members **25.1, 25.2** in vehicle roof **17** and upper member **8.17** of door frame subjected to lateral load „F_o" in real-world accidents. The lack of interengaging assemblies became obvious on the rollover of a sport car, which plunged seven meter downwards and crashed with vehicle roof **17** into a lower level of an underpass in Wiesbaden City thus totally deforming vehicle roof **17**, body **20** and both upper members **8.17** of door frames during rollover, where the remaining energy was transmitted through both head rests, integrated into the respective seat backrests, to the vehicle floor, thereby reducing the AIS of both passengers. AIS is an international acronym of Abbreviated Injury Severity ranging from 0 (unscathed) to 6 (fatality).

Responsive to problem case **E**, adjustable and/or door locks are provided for interengaging assemblies, whose adjustable and/or latchable keys are bolted to the B- or C-pillar, facing the termini of both reinforcing beams **1, 7** or **1B, 7B**, and whose mating receptacles are arranged thereto. Both plates **5.1, 5.2** of each hinge of vehicle door are provided with a rivet, serving as a key, and an oblong mating hole. Owing to this feature load cases **I to IV** are resolved, but load case **V** and problem cases **E3 to E5** remain unresolved.

Evidently, failure of "interengaging" assemblies of the remaining prior art to ensure the interengaging the mating members thereof is due to the wrongly idealized force, wrong boundary conditions and a number of large tolerances such as five tolerance zones, proposed by U.S. Pat. No. 5.297,841, U.S. Pat. No. 4,307,911, and eight tolerance zones, proposed by U.S. Pat. No. 5.806,917.

In view of foregoing shortcomings and deficiencies, there is a need to ensure the operation of interengaging assemblies associated with the integration of the vehicle doors into the vehicle body in order to increase the stiffness of the vehicle structure and prevent passengers from ejection out of the vehicle or from intrusion of vehicle side in real-world accidents.

SUMMARY OF THE INVENTION

Accordingly, the principle object of the present invention is to provide for vehicular couples of a motor vehicle interengaging assemblies equipped with adjusting mechanisms to adjust large clearances, which result from manufacturing vehicle members and from car assembly, to permissible tolerances thus ensuring the operation of interengaging assemblies associated with the integration of the vehicle doors into the vehicle body in order to increase the stiffness of the vehicle structure and prevent passengers from ejection out of the motor vehicle or from intrusion of the respective vehicle side in real-world accidents.

A second object of the present invention resides in interengaging assemblies, with or without adjusting mechanisms, arranged to the vehicular couple in at least two operating planes or in dissimilar operating planes to sustain forces of load cases in three different planes and ensure the engagement thereof in association with energy distribution to the respective vehicular members thus making the strict restriction of permissible tolerances less significant, enormously cutting assembly time and preventing from total deformation.
Figs. 14 to 18 illustrate a single vehicular couple such as window-guide channel & B-pillar with the interengaging assemblies such as keys **34** & holes in z-x plane acting as the first operating plane, however, interengaging assemblies such as keys **32, 33** & holes in z-y plane acting as the second operating plane. The specification is changed from the permissible tolerances of "narrow" to small tolerances of "far less narrow", thus cutting costs and time resulting from less adjustment work to reduce large clearances thereto.
This feature of dissimilar operating planes is applicable too for both interengaging assemblies such as holes & **15.1, 15.2a** and **15.2, 15.3** and **15.4a, 15.5** etc., shown in **Fig.** 3. A row of the same keys is operative in dissimilar operating planes by arranging a number of the same keys **15.1** to the generally inclined A-pillar or of keys **33** to the generally inclined B-pillar. In reference to the global xyz coordinate system the key **15.2a** & hole is operative in an inclined plane.
Because the hinge bolts of the front and rear doors have an operating direction in z-axis the arrangement of interengaging assemblies such as holes & keys **31, 36** to one operating plane is sufficient. However, any additional arrangement of holes & keys **30, 35** improves the engagement of the vehicular couples and substantially decreases severe/fatal injuries in any real-world accident.
By means of arrangement of interengaging assemblies of each vehicular couple in multi-operating planes and increase of vehicular couples comprising vehicle door & vehicle roof **17**, vehicle door & side rail **18**, vehicle door & pillar/s and vehicle door & vehicle body **20** more vehicular members in compound construction are involved in energy absorption in different load cases in the event of any collision and/or rollover.
In co-operation with another prior art the structural stiffness reaches the maximum.
Beyond doubt, the advantage of keys *2.1, 5.6* & mating holes is attributed to the further exploitation of the very stiff impact beams **1, 7** to house the corresponding members. Because the other vehicular couples comprising such as vehicle door & side rail and vehicle door & vehicle roof are not equipped with interengaging assemblies this *single* arrangement of one vehicular couple in mid-region of door is insufficient in the event of any collision and/or rollover, in which the passengers are squashed to death by intrusion of vehicle roof **17** into the vehicle body and of upper member **8.17** of door frame as well as buckling of the upper portion of the A-pillar. total deformation of upper member **8.17** of door frame, buckling of vehicle roof **17** and buckling of side rails **18**, shown in **Fig.** 8.
In order to avoid the above-mentioned state of total deformation a number of holes or keys **30 to 37** is arranged to the flange **21** *above, below* of the impact beams **1, 7** and *therebetween.*
When the *non-adjustable* rivets *5.6* of the door hinges in x-z operating plane are replaced by a number of interengaging assemblies **15.1, 15.2a, 15.4, 30, 31** in numerous operating planes, the total stress of the vehicular couples such as A-pillar & vehicle door along the z-axis is lower owing to stress distribution, thereby preventing, to a certain extent, the A-pillar and vehicle door from total deformation and gap „o", shown in **Fig.** 8.

A third object of the present invention resides in space-saving, inexpensive, labour-time saving design for engaging keys which are installed on the respective vehicular members and adjusted to the respective receptacles from outside the vehicle body in order to enormously cut assembly time.

A fourth object of the present invention resides in window-guide channels and flanges of the vehicle body all of which are exploited to accommodate the members of interengaging assemblies thus saving costs, lowering stress and boosting sales associated with overall stylish impression.
The flange **21, 21T, 21h, 21x** of vehicle body **20**, provided with sound-proofing material **21.10**, shown in **Figs.** 1, 17, 18, serve as sites to accommodate keys or receptacles. An enlargement of the flange to a limited extent neither impairs the overall stylish impression nor obstructs passengers from ingressing into or engressing from the passenger compartment. Those regions of all pillars are defined by the dotted lines "a1", "b1", "b2" and "c1".
As substitutes of the bulky bolt ref. to U.S. Pat. No 3,819,228 small-size parts can be distributed in inconspicuous manner along the window-guide channels as well as flange, thus substantially ensuring the engagement of vehicular couple whilst lowering stress.
Owing to this feature it is possible to arrange the following keys such as

- **30, 32, 35, 37** to the respective flange **21** of vehicle body **20**. In contrary to U.S. Pat. No. 3,819,228, this feature won't endanger passenger when stepping in or out, furthermore, more useful for passenger protection in a side collision, particularly, according to collision types „U1" and „U2", shown in **Fig.** 13, as well as in a front collision.
- **15.2a, 15.2, 15.7**, for example, with bolts M4 to the narrow window-guide channel **6.3, 6.3B** of upper member **8.17** of door frame to resolve the problem of the large, stiff contour groove of the prior art.
- **33, 34, 36** to the respective window-guide channels **6, 6B** and channels **6.7, 6.8** in engagement with the reinforced B-pillar in two to three operating planes without obstructing the operation of the seat belt **26.1**, shown in **Fig.** 15. The fact, that no contact is made during the opening operation of juxtaposed vehicle doors, is demonstrated by the trajectories of both outer points of the washer and of the door edges drawn with dotted lines.
- **31** to the respective window-guide channels **6** and channels **6.6a** in engagement with the reinforced A-pillar.

A fifth object of the present invention is to provide for a common pillar of juxtaposed vehicle doors at least one U-shaped pillar-reinforcement member to receive at least one pair of keys which are in engagement with mating receptacles, located on the respective door-frame members of those doors, when closed, for exploiting a constrained deformation thereof, of the respective side rail and/or roof in order to ensure the interengagement thereof and prevent those doors from popping open in real-world accidents. Owing to the engagement of keys **15.3, 15.3a, 15.5, 15.5a** with the mating apertures, arranged to the corresponding window-guide channels **6.2a, 6.1aB** of juxtaposed doors **8, 8B**, when closed, the U-shaped pillar-reinforcement members **17.3, 18.3**, shown in **Fig.** 3, serve as connection elements of the common pillar to the vehicle roof, juxtaposed doors and side rail. Another pillar-reinforcement member **23**, shown in **Figs.** 15 and 16, serves as a connection element of the common pillar to the juxtaposed doors owing to interengaging assemblies **33, 34, 36** & mating receptacles.
Alternatively, interengaging assemblies, comprising hooks **15.6** & stiff rod **17.1d**, shown in **Fig.** 4, serve as connection elements of the juxtaposed doors to the common pillar, vehicle roof, and side rail.

A sixth object of the present invention resides in transverse girders of vehicle roof, side rails and all pillars facing each other to ensure energy transmission from one vehicle side into the other and distribute energy thereto.

A seventh object of the present invention is to provide for each rear door a rear-door member to receive at least one pair of engaging members of interengaging assemblies in engagement with mating engaging members, located on the respective C-pillar to ensure the engagement of the rear doors with the respective C-pillars in rear collisions. Door detachment in rear collision occurs due to the lack of door hinges and interengaging assemblies. For the purpose of connection of vehicular members to each other the engagement of rear door **8B** with the C-pillar is improved by rigidly arranging

- rear-door member **6.5C,** adapted to the outer door-panel contour and having holes to receive mating keys **37**, shown in **Figs.** 14, 18, to the door frame of rear door; and
- keys **33, 34** to window-guide channel **6B**.

The features of vehicle door are, doubtless, suitable for tailgate door **8T**, sliding side door, liftgate door cargo door, trunk cover **8x**, hood **8h**, juxtaposed doors, for example, three vehicle doors with four pillars of large van.

BRIEF DESCRIPTION OF THE DRAWINGS

A number of embodiments, other advantages and features of the present invention will be described in the accompanying drawings with reference to the xyz global coordinate system:

Fig. 1 is a side view of a vehicle side, a vehicle body, impact beams, keys, hooks, window-guide channels serving as door-frame members.

Fig. 1A is a cross-sectional view of a vehicle door engaging with a roof and side rail ref. to DE-OS 2162071 in a side collision.

Fig. 1B is a cross-sectional view of a vehicle door engaging with a side rail ref. to EP 0423465 A1 in a side collision.

Fig. 2 is a side view of an U-shaped window-guide channel, the position of keys **15.7, 15.8** and an additional window-guide member **6.4, 6.4B.**

Fig. 2A is a side view of an U-shaped window-guide channel, the position of keys **15.7**.

Fig. 3 is a perspective view of a front stiff door frame with both window-guide channels, both respective window-guide channels and interengaging assemblies of the 1st embodiment.

Fig. 3A is a cross-sectional view of a key equipped with an adjusting mechanism.

Fig. 4 is a perspective view of an interengaging assembly hooks & stiff rod of the 2nd embodiment.

Fig. 4A is a cross-sectional view of the stiff rod and the mating hook equipped with an adjusting mechanism.

Fig. 5 illustrates a load case I in z-y plane in a front collision of motor vehicle.

Fig. 6 illustrates a load case II in z-x plane in a front collision.

Fig. 7 illustrates a load case III in x-y plane in a front collision.

Fig. 8 is a state of total deformation of a motor vehicle at displacement „v" in a front collision.

Fig. 9 illustrates a load case IV in x-y plane in a side collision of a motor vehicle.

Fig. 10 illustrates a load case V in z-x plane in a side collision.

Fig. 10A illustrates the mating members of interengaging assemblies ref. to U.S. Pat. No 4,307,911, both mating members of a door lock, the general force „F_1" or „S_1" in the event of a front or side collision and a crash into a highway column.

Fig. 11 is a view of a compression-coil spring on a lower spring seat.

Fig. 12 illustrates the projection of the end coil and spring seat in a plane, the test results and FEM data of an end coil rolling on the lower spring seat in dependence on load.

Fig. 13 illustrates four collision types „U1" to „U4" ref. to the research work of Institute of Vehicle Safety, a Dept. of German Insurers Association, and a crash of a motor vehicle into a highway column.

Fig. 14 is a perspective view of interengaging assemblies of the 3rd embodiment comprising a stiff front door frame having a single window-guide channel and a stiff rear door frame having a single window-guide channel to engage with the pillars and flange of a vehicle body.

Fig. 15 is a cross-sectional view of the front and rear door, both in juxtaposition, in engagement with the A-, B-pillar and the vehicle body along the line D-D in **Fig.** 14.

Fig. 16 is a side view of the juxtaposed stiff door frames without window pane in engagement with the B-pillar according to arrow E in **Fig.** 14.

Fig. 17 is a perspective view of interengaging assemblies of the 4th embodiment comprising a stiff front door frame having a single window-guide channel in engagement with the flange of a vehicle body.

Fig. 18 is a side view of the flange of a vehicle body provided with keys.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Beyond doubt, the function of the interengaging assemblies is well described in the preferred embodiments of the prior art. However, the tolerances, for example, eight tolerance zones of each interengaging assembly ref. to U.S. Pat. No. 5,806,917, are totally neglected in the scope because the explanation of how to assemble and manufacture the interengaging assemblies in relation to the **Figs.** is omitted. Hence, this subject must be taken into account when the function and assembly of the interengaging assemblies is described in conjunction with manufacturing parts thereof, distributing energy to the vehicular members and increasing the vehicle stiffness. When the door is closed, the interengaging assemblies in engagement are capable of ensuring the connection of the door with the vehicle body under the premise that the tolerances between the mating members thereof are well defined.

Ref. to **Fig.** 3, the scope of the application of the window-guide channels of vehicle door is extended to accommodate the keys of interengaging assemblies, whose mating receptacles are arranged to any (A-, B-, C- or D-) pillar, flange of vehicle body, vehicle roof and/or side rail. This feature saves weight and costs. The positions of keys and mating receptacles may be interchanged if desired.

According to the prior art a stiff door frame of vehicle door can be assembled from at least two impact beams, door-frame members and at least one window-guide channel, shown in **Figs.** 1 and 3. As is customary, conventional window-guide channels **6.1, 6.2, 6.1B, 6.2B**, shown in **Figs.** 1 and 3, are made from U-shaped thin panel. The window-guide channels **6, 6B, 6.1, 6.2, 6.1B, 6.2B, 6.1a, 6.2a, 6.1aB, 6.2aB**, serving as door-frame members, are of higher-grade tensile strength **6.1a, 6.2a, 6.1aB, 6.2aB** to receive keys (hooks), mating receptacles, door-reinforcement members **6.5, 6.5B, 6.6a, 6, 6b, 6.7a, 6.7b, 6.8, 6.9** (not drawn), to reinforce the door frame, to span the door aperture and to distribute impact energy to the vehicle roof, side rail and pillar(s).

The door-reinforcement members **6.8, 6.9**, shown in **Fig.** 14, are rigidly attached to the front faces of both impact beams **1B, 7B** and the window-guide channel **6B**, the door-reinforcement members **6.6b, 6.7b** are rigidly attached to the window-guide channel **6** and impact beam **7** and the door-reinforcement members **6.6a, 6.7a** are rigidly attached to the window-guide channel **6** and between both impact beams **1, 7**.

Both window-guide channels are replaceable by a conventional U-shaped stiff window-guide channel **6, 6B**, shown in **Figs.** 2, 2A, 14 to 17. Less stiff window-guide members **6.3, 6.3B** are normally made of panel. Alternately, very stiff window-guide member **6.3, 6.3B** serves to receive the window pane and keys **15.7**.
Window-guide channel **6, 6B** provided with window-guide member **6.3, 6.3B** in the door cavity, shown in **Fig.** 2A, has open ends. To maximize the stiffness of window-guide channel **6, 6B** both ends are rigidly connected to each other by a window-guide member **6.4, 6.4B** in the door cavity, shown in **Figs.** 2, 14 to 17, after the window pane has been inserted. Alternately, the window-guide member **6.4, 6.4B**, having flat profile, receives window pane **60, 60B**, shown in **Fig.** 15, and, finally, is secured against falling down by protective parts.
The window-guide member **6.4, 6.4B** is useful for the accommodation of keys **15.8**. If extraneous weight is not that important for heavy cars, trucks and vans, the window-guide channel, fastened to the impact beams, serves as members of door frame to receive keys while guiding and receiving the window pane.

To solve the problem case E4, distribute impact energy to pillar, door **8, 8B**, roof **17** and side rail **18** and transmit it from one vehicle side to the other vehicle side a design is featured in the 1st embodiment, shown in **Fig.** 3, by means of arrangement of keys **15.1** to the reinforced A-pillar and mating oblong holes to the window-guide channel **6.1a**, of keys **15.2** to the window-guide channels **6.1a, 6.2a** and mating holes to a reinforcing plate **17.1a**, arranged along the vehicle roof, of keys **15.4** to a reinforcing plate of side-rail reinforcement member **18.1**, arranged along the side rail, and mating holes to window-guide channels **6.1a, 6.2a** and of key **15.1** to a reinforcing element of the L-shaped A-pillar, welded to a reinforcing plate **17.1c** arranged along the vehicle roof and to transverse girder **17.2d** of both facing A-pillars of both vehicle sides, and mating oblong hole to the window-guide channel **6.1a**.
High stress resulting from the load case **IV** becomes apparent when large-sized doors are designed to enhance the comfort of passengers when stepping in and out of the vehicle. To resolve this drawback additional keys **15.2, 15.4** are arranged to the window-guide channel **6.3** and member **6.4** and mating holes to the reinforced vehicle roof and the reinforced side rail, respectively.

Ref. to **Fig.** 4, the 2nd embodiment consists of an interengaging assembly, whose hooks are attached to two window-guide channels of each vehicle door and the mating rod to the vehicle roof, pillars of the door or all doors. Additionally, the rod serves to reinforce the vehicle roof, sustain impact force and aid positioning on assembly, thus cutting costs and time at the assembly line. However, this embodiment needs space, which is available in large cars, trucks and vans. This embodiment is suited too for another vehicular couple comprising vehicle door/s & side rail.
The interengaging hooks **15.6** are bolted to the window-guide channels **6.1a, 6.2a, 6.1aB, 6.2aB** and the mating stiff rod **17.1d** is arranged along the vehicle roof **17** and/or side rail **18**. When at least one pair of rods is welded to transverse girders **17.2e, 17.2f, 17.2g** of both A-, B- and C-pillars, energy can be distributed from one vehicle side to the other vehicle side in a side collision, from the front to rear vehicle section of vehicle body **20** in a front collision, from the rear to front vehicle section of vehicle body **20** in rear collision or to all members of vehicle body **20** on rollover.

Ref. to **Figs.** 14, 17, 18, the 3rd embodiment consists of interengaging assemblies **30 & 6.5, 35 & 6.5B** and other interengaging assemblies **32 & 6.9, 37 & 6.9B (6.9, 6.9B** similar to **6.5**), **37 & 6.5C** for the purpose of avoiding large deformation of the edges of each door and of saving costs by exploiting the flange **21** of vehicle body **20** and the enlarged flange defined by the dotted lines "a1", "b1", "b2" and "c1" to receive keys. The keys **30, 32, 35, 37** are bolted to the respective flange-reinforcement members **21.1** to **21.5, 21.1B** to **21.5B** of the flange **21** of vehicle body **20** and the corresponding holes are arranged to the housings **6.5, 6.5B** and/or rear-door member **6.5C**, all of which are rigidly attached to the respective window-guide channels **6, 6B**, the respective members **6.6b, 6.7b, 6.8, 6.9** (not drawn because of the similarity to **6.7b**) and/or the respective impact beams **1, 1B, 7, 7B**. The reinforcing element **21.5B** is welded to the flange and rear wheel case. The same reinforcing method can be employed to arrange a similar element **21.1** to the flange and the front wheel case.
Stiff door hinges in co-operation with the impact beams **1, 7, 1B, 7B** and interengaging assemblies transmit forces of load case **I** from the front to rear vehicle section of vehicle body **20** in a front collision. There are no door hinges to connect the rear door to the C-pillar. To avoid the detachment of rear doors and improve energy transmission from the rear to front vehicle section of vehicle body **20** in rear collision, a rear-door member **6.5C** is attached to the impact beams **1B, 7B**.
Instead of the bulky "engaging" bolt ref. to U.S. Pat. No. 3,819,228 these keys, configured in small size and distributed along the flange, neither spoil the overall design nor injure persons, stepping in or out of the vehicle body, nor overstressing the vehicle members.

In the 4th embodiment the Technical Mechanics Method of constrained deformation is applied to ensure the engagement of all vehicular members with each other in the event of accidents and to distribute impact energy thereto by means of two U-shaped pillar-reinforcement members **17.3, 18.3**, located in a common pillar, shown in **Fig.** 3, whose keys **15.3, 15.3a, 15.5, 15.5a** are engaged with the mating apertures, arranged to the corresponding window-guide channels **6.2a, 6.1aB** of juxtaposed doors **8, 8B**, when doors are closed. Serving as a connection element of the common pillar with the vehicle roof and juxtaposed doors, this U-shaped pillar-reinforcement member **17.3** is welded to a reinforcing plate **17.1b**, arranged along the vehicle roof **17**, and to a transverse girder **17.2c** of both facing common pillars of the vehicle sides. Serving as a connection element of the common pillar with the vehicle floor and juxtaposed doors, this U-shaped pillar-reinforcement member **18.3** is welded to a side-rail reinforcement member **18.1b**, arranged along the vehicle floor, and to a transverse girder **18.2** of both facing common pillars of the vehicle sides. The belt casing **26** can be housed in the U-shaped pillar-reinforcement member **18.3**.
When in the real-world accidents, above-mentioned in the problem cases **E3** and **E5**, the side rail **18** or vehicle roof **17** deflects inwards, conventional interengaging assemblies become disengaged. Large inward deflection of the side rail or vehicle roof deforms the pillar-reinforcement member **18.3** or **17.3**, which constrainedly deforms the common pillar, juxtaposed doors and the vehicle floor or the vehicle roof thus ensuring the engagement of the juxtaposed doors with the vehicle body and preventing passengers from ejection out of the vehicle, when rolling over.

Due to the arc-travel path of the door about the mutual axis of door hinges the mating surfaces of a key and receptacle of each interengaging assembly, proposed by U.S. Pat. No. 5,806,917, are configured in four tapered forms or two curved and two tapered forms, thus yielding eight tolerance zones, high manufacturing and assembling costs as well as making tight engagement impossible resulting in door detachment in accidents. To resolve these problems straight (non-curved, non-inclined or non-tapered) engaging surfaces are

proposed for keys and receptacles. The purpose of assembling and adjusting any key, shown in **Figs.** 3, 3A, 4 and 4A, from outside of the vehicle body **20** is to substantially cut labour time and costs. Manufacturing costs can be enormously lowered by using mechanical standard parts like washer, hexagon socket head bolt etc. With the exception of **15.4a** each key **15.1 to 15.5a, 15.7, 15.8, 30 to 37** comprises a bolt **15.14**, a sleeve **15.11**, a number of washers built into one spacer **15.12** and a washer with a large exterior diameter **15.13**, illustrated in **Figs.** 3A, 14 to 18. In order to ensure the engagement of a key with the mating hole a protrusion „x_n" and circumferential clearance „c_c", explained in the next section, must be preserved by correcting the length of the spacer „l" by removing or adding washers and/or assembling a sleeve with exterior diameter „d", washer with exterior diameter „D" and/or spacer with diameter „d_K".
If desired, the sleeve **15.11** and spacer **15.12** can be made of soundproofing material.

Each hook **15.6**, shown in **Figs.** 4 and 4A, comprises a hook **15.20** with interior diameter „d_1" and gap „s_1", smaller than „d_1", a bolt **15.21**, a number of washers built into one spacer **15.22**, a coil-spring washer **15.24** and a nut **15.25**. The symbols „s_1", „d_1" and „d_2" are shown in **Fig.** 4A. In order to ensure perfect engagement of the hooks with stiff rod **17.1d**, having diameter „d_2" smaller than „s_1", small tolerance zones, shown in **Fig.** 4A, must be preserved when a hook with gap „s_1" and a rod with diameter „d_2" are assembled under the premise of the distance „l_1", which is corrected by removing or adding washers, and/or of properly positioning the centres of the hook hole and the stiff rod when out of alignment. Advantageously, the rod **17.1d**, reinforcing the side rail **18** or vehicle roof **17**, enhances the stiffness of vehicle structure and avoids in a great extent buckling thereof.

Fig. 15 exemplifies another feature of numerous different planes, in which the interengaging assemblies of any vehicular couple comprising, for example, the common or B-pillar and the juxtaposed vehicle doors **8, 8B**, operate. When the doors are closed, a key **33** protrudes the mating hole by „$-x_n$" (minus sign in respect to the opposite x-direction), which is limited due to the arc-travel path of the door about the axis of door hinges. The clearances of the key **33** and the mating hole are denoted by „$-y_n$" and „y_p". The protrusion „x_n", circumferential clearance „c_c" (not drawn, represented by „$-y_n$" and „y_p" in y-direction) of the mating members of each assembly and the operating plane play a significant role on tight engagement thereof in real-world accidents. In the real-world accidents, above-mentioned in the problem cases **E2** and **E3**, the door becomes detached due to large circumferential clearances of all mating members of interengaging assemblies, which operate in the same z-y plane, and large inward deflection of the vehicle body **20** or side rail **18** in the opposite x-direction, during which under the load of inertia forces of the passenger the door is opened and moved in the arc-travel path about the axis of door hinges. Door detachment can be prevented by permissible tolerances, whereby the mating members of interengaging assemblies of any vehicular couple, acting in the same operating plane, are governed.
In this time- and cost-saving feature against door detachment, proposed for the following embodiments, many interengaging assemblies of any vehicular couple comprising, for example, interengaging assemblies keys **32, 33, 34** & mating holes, must operate in numerous different operating planes, where the deformation of door **8** results in a tight engagement of keys **32, 34** with the mating holes, taken, the worst case is given, that all keys **33** fail to engage with the mating holes. The interengaging assemblies, comprising keys **32, 33, 34** & mating holes, operate in three different operating planes, the number of which can be increased by arranging these interengaging assemblies in the operating planes, which, however, are offset to each other, for example, in offset z-y planes. The interengaging assemblies keys **35** & holes act in the fourth operating z-y plane and keys **36** & holes in the fifth operating z-x plane. Owing to this feature the permissible tolerances of "narrow" are

outdated, hence, replaced by small tolerances of "less narrow", "far less narrow", "small" and/or "medium", thus significantly lowering the reject rate, assembly time and costs. Advantageously, a pattern of the interengaging assemblies, governed by permissible tolerances, can be issued in a table handed to assembly workers. Alternately, this pattern can be coded in the assembly program to drill, position and assemble members thereof within the permissible tolerances. The constant, small contour clearance and the proper tolerance between catch plate **248** and striker **298**, above-mentioned in the problem cases **D** and **E**, can easily be accomplished at the assembly line within short time, thus making rework as well as adjustment work superfluous.
It must always be reckoned with a reject when the assembly tolerances are, unexpectedly, larger than the permissible tolerances. Adjustment work for the interengaging assemblies of the rejected car can be done outside of the assembly line, thereby the production process is not halted and the reject rate of zero is met.
All these advantages outweigh the costs of extra material for a larger number of interengaging assemblies.
A washer **15.13** with radial teeth, serving as a part of key **33**, clamps in the inner region of the reinforced B-pillar in any collision or on rollover. As an integral part of a bolt the washer won't come loose on assembly.
Costs can be cut by positioning an unadjusted key between adjustable keys, such as rivet **15.4a**, fastened to the reinforcing plate of side-rail reinforcement member **18.1a** arranged along the side rail. However, when the number of the interengaging assemblies is limited in a low-cost configuration, for perfect interengagement the provision with keys **15.1 to 15.8, 30 to 37** without key **15.4a** is ultimately necessary.

Large total stress of the load cases, for example, **I to III** results in total deformation (buckling) of the pillars, side rail, vehicle roof and/or doors because stress of vehicle body and doors in a real-world accident can never be predetermined in the research and crash tests, three of which are mentioned in the problem case **E4**, due to the collision type, the boundary conditions and properties of two masses colliding against each other. Four front collision types are shown in **Fig.** 13. In a real-world accident a front, side and/or rear collision can end up in a pile-up or on a rollover, thus increasing the number of collision types and making a FEM calculation impossible. To resolve such indeterminate stress the vehicular couples comprising front pillar & door **8, 8B**, rear pillar & door **8, 8B**, vehicle roof **17** & door **8, 8B** and side rail **18** & door **8, 8B** must be equipped with many interengaging assemblies operating in numerous planes, such as keys **30** & holes acting in the first operating z-y plane, keys **31** & holes acting in the second operating z-x plane, key **15.2a** & hole, shown in **Fig.** 3, acting in the third operating z-y plane and in co-operation with additional interengaging assemblies, the mating members of which may be chosen among the keys **15.1, 15.2, 15.3, 15.3a, 15.4, 15.4a, 15.5, 15.5a, 15.6 to 15.8, 32 to 37** and mating receptacles in the above-mentioned embodiments.

Although the present invention has been described and illustrated in detail, it is clearly understood that the terminology used is intended to describe rather than limit. Many more objects, embodiments, features and variations of the present invention are possible in light of the above-mentioned teachings. Therefore, within the spirit and scope of the appended claims, the present invention may be practised otherwise than as specifically described and illustrated.